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THE CALCIUM CONTENT OF THE FOLIAGE OF FOREST TREES

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The soils in regions of relatively high rainfall are generally acid in reaction. This is owing primarily to the leaching of exchangeable calcium from the soil and its replacement by hydrogen. In a soil that is derived from calcareous rock, however, some reserve of calcium carbonate may still be present, and hence such a soil would be neutral or slightly alkaline in reaction.

Agricultural soils that are somewhat acid in reaction are often treated with some form of lime in order to replace some of the calcium previously lost through leaching. Such a practice is not economically feasible for most forest soils. There is a natural process, however, which acts to conserve the exchangeable and water-soluble forms of calcium in forest soils. The leaves of forest trees may contain considerable amounts of calcium which is returned to the soil each fall. This calcium, if present in relatively large quantity, tends to maintain the exchangeable-calcium content of the surface soil at a comparatively high level. Since this calcium originally comes from some part of the soil on which the trees are growing, the process cannot be compared exactly to that of adding lime. Nevertheless the effect upon certain soil characteristics is similar, because in both cases the influence is largely confined to the exchangeable and water-soluble forms of calcium. In addition, if the roots of the trees did not absorb some of this calcium it would be lost in the drainage water. Therefore high-calcium-absorbing tree species tend to decrease losses of calcium through leaching, and, on rather acid soils, will actually increase the exchangeable-calcium content of the soil even though the total calcium content is gradually decreasing.

The calcium content of the foliage of different forest-tree species may vary by more than 500 per cent. This range is greater than that for any other essential mineral element which has been studied. Furthermore, all of this calcium is returned to the soil at the time of leaf-fall. This is not the case with nitrogen, phosphorus, and potassium, which characteristically evince an autumnal migration back into the woody parts of the tree.

A knowledge of the calcium content of the foliage of different forest trees is important for several reasons: (1) the pH and the percentage base saturation of the surface soil are markedly affected by the amount of calcium deposited in the tree litter; (2) the number and the activity of nitrifying bacteria in the soil are generally increased beneath stands which deposit high amounts of calcium; (3) the rate and degree of incorporation of organic matter into the soil is highly correlated with the calcium content of the litter; (4) the physical structure of the soil is generally improved by litter with a high calcium content. Certain of these effects are only indirectly related to the calcium content of the litter, but nevertheless the conditions would not prevail if the calcium were not present.

Other bases, of course, act similarly, but evidence indicates that the influence of the calcium outweighs that of all the other bases combined. This is owing in part to the relatively large amount of calcium present, as well as to the nature of the cation.

It is the purpose of this paper to report the seasonal trends in calcium content of the foliage of certain forest trees, and to present data concerning the average calcium content of mature foliage of the more common forest trees of the northeastern United States in order to provide a means of rating different forest trees with respect to their influence on the calcium content of the surface soil.

REVIEW OF LITERATURE

Several workers have analyzed the leaves of forest trees at different times during the growing season (McHargue and Roy, 1932; Deleano and Bordeianu, 1933; Alway, Maki, and Methley, 1934; Mitchell, 1936). These workers consistently report a steady increase in calcium content up to the time of leaf-fall, this applying whether expressed as percentage of dry matter or as the absolute amount in a given number of leaves. When the analyses were plotted against the age of the leaf, the steepness of the slope was generally proportional to the total amount of calcium accumulated at the time of leaf-fall. No data have been found showing the seasonal trends for different-aged needles of coniferous trees.

In addition to the references cited above, other workers have reported the calcium content of the foliage of trees at the time of leaf-fall (Plice, 1934; Coile, 1937; Chandler, 1937 b). In most cases only a few species were reported on by any one worker, and, since relatively few species were common to several sampling localities, comparisons of figures for the same species on different sites were necessarily rather limited in number. The results showed, however, that there was a distinct tendency for certain species to be high in calcium and for certain others to be low, regardless of the locality in which they occurred.

Data have been presented also to show some of the influences of the calcium content of the foliage of forest trees upon certain characteristics of the soil. Some of the papers giving such data are reviewed in the following paragraphs, to indicate the importance to be attached to variations in the calcium content of foliage.

Coile (1933), working in North Carolina, showed that the species of tree strongly influences the pH of the A_0 and A_1 horizons. In a later article (1937) he presented data to show that species which produce a high pH in the surface soil contain high amounts of calcium in their litter. If the results of these two studies by Coile are combined, the following statements can be made: in stands consisting of red cedar or of red gum and yellow poplar mixtures, and with the calcium content of the litter averaging more than 2 per cent, the pH of the H-layer would range from 6.3 to 7.0; beneath stands of shortleaf or loblolly pine, with the litter averaging less than 0.6 per cent calcium, the pH of the H-layer would be less than 5.0.

Shear and Stewart (1934) showed a definite relationship between tree species and soil pH. They did not report any values for calcium content

of the litter; but by substituting values obtained in this study, a high positive correlation was found to exist between pH and calcium content of the foliage.

The writer (Chandler, 1937 a) has demonstrated the influence of the litter of certain species upon the pH and the percentage base saturation of the soil. In all cases a relatively high calcium content of the foliage was found with both a high pH and a high percentage base saturation of the surface soil. More recently (Chandler, 1939) a similar relationship has been shown for soils in the Adirondack region. Here the influence on the morphological characteristics of the soil profile were very striking, the higher-calcium litter producing conditions favorable for the formation of a fine mull (Heiberg, 1937) humus layer and a brown podzolic soil of the Essex sandy loam type, and the low-calcium litter producing conditions favorable for the formation of a granular mor (Heiberg, 1937) humus layer and a mature podzol profile of the Beckett sandy loam type. In both cases the soils were of similar geological origin.

Diebold (1935) and Romell (1935) have indicated that the humus-layer type is partially determined by the tree species.

Plice (1934), working in New York, showed that with many species the antacid-buffering capacity of the litter is highly correlated with its calcium content. Certain species, however, showed a fairly high buffering capacity even when the base content was low. Plice determined the pH of the soil beneath single large trees in mixed hardwood-coniferous stands, and found that the hardwoods generally produced a higher pH in the soil than did the conifers.

Although Griffith, Hartwell, and Shaw (1930) did not make interpretations on the basis of calcium content of the litter, they showed that the incorporation of organic matter is increased and the depth of the surface accumulation of organic matter is decreased by the presence of certain deciduous tree species as compared with white pine.

EXPERIMENTAL METHODS

The leaf samples used in the study of seasonal trends were obtained from trees on Dunkirk silt loam soil at Ithaca, New York. Certain trees were selected in various woodlots at the beginning of the growing season of 1936, and were sampled in duplicate every fifteen days until October 1. From 30 to 100 leaves constituted a sample, depending upon the size of the individual leaves. The samples were collected between 9 and 11 a.m. and were put into aluminum cans, and their fresh and dry weights were determined.

The leaf samples for determination of calcium content of mature foliage were obtained in September of 1936, 1937, and 1938. There was no uniformity as to the time of day when the samples were collected. The trees sampled were growing on acid soils, usually Lordstown stony silt loam. Some of them were on Beckett and Essex sandy loam soils in the Adirondack region, this applying particularly to such species as red spruce and balsam fir which do not occur in south central New York.

All leaves in both studies were taken from branches that were exposed to full sunlight during a part of the day, and usually the leaves were taken from the upper part of the crown of dominant trees. After collection the

leaves were dried for twenty-four hours at a temperature of about 70° C. They were subsequently ground in a hammer mill so as to pass through a 60-mesh sieve.

The material was ashed in a muffle furnace at a temperature of about 750° C. The ash was taken up with 2N.HCl and the calcium content was determined by the usual oxalate-precipitation method, the oxalate being titrated with potassium-permanganate solution.

EXPERIMENTAL RESULTS

SEASONAL TRENDS IN CALCIUM CONTENT OF FOLIAGE

Data on seasonal trends in the calcium content of foliage were obtained for the following species: beech, cucumber tree, trembling aspen, red cedar (new and old foliage), and white pine (new, one-year, and two-year needles).

The figures for the percentage calcium content, the dry weight of 100 leaves, and the absolute amount of calcium in 100 leaves, for the three deciduous species, are given in table 1. The data on calcium content are shown graphically in figures 1 and 2. The assumption was made that small variations from a smooth curve were due to experimental error (largely sampling error) and hence were of little significance. Therefore a free-hand curve was drawn through the data in order to denote the general seasonal trends in calcium content of the leaves.

The curves in figure 1 indicate that there was a distinct tendency for the percentage calcium content to increase throughout the growing season. The curve for beech showed the least tendency for an increase,

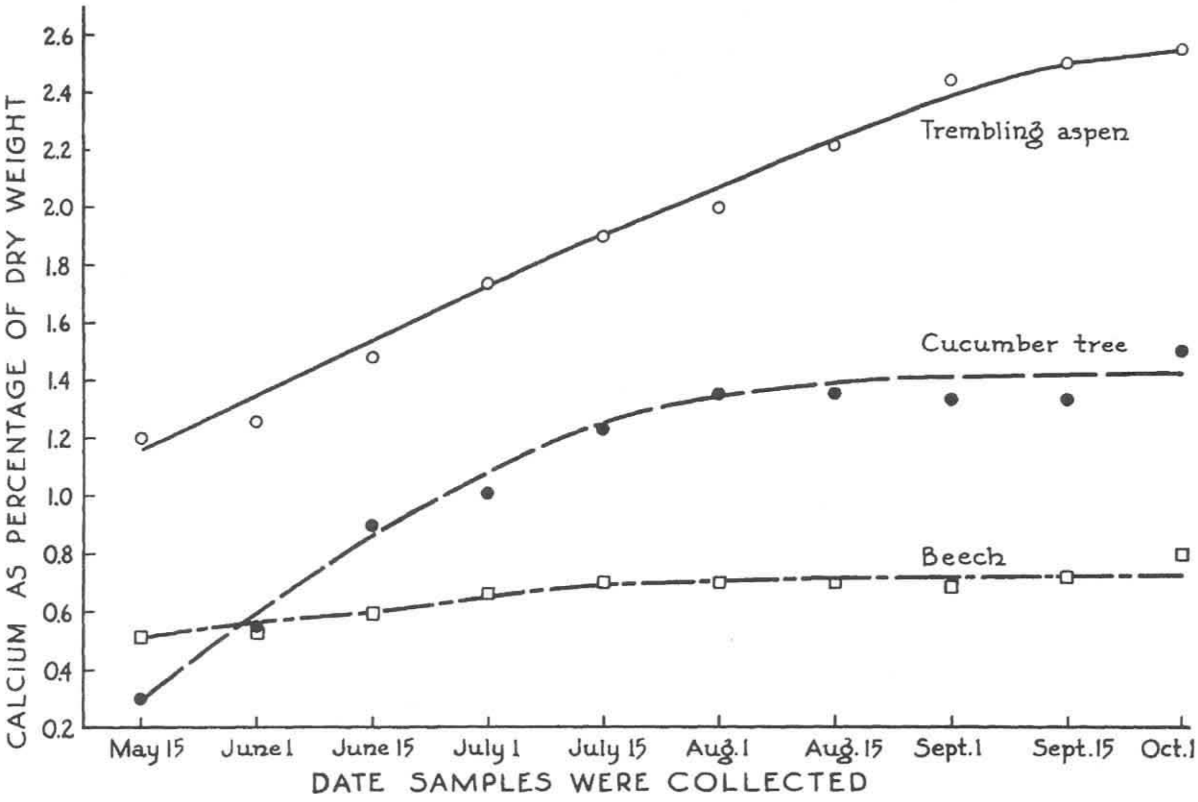

FIGURE 1. CALCIUM CONTENT OF THE LEAVES OF BEECH, CUCUMBER TREE, AND TREMBLING ASPEN THROUGHOUT THE GROWING SEASON, EXPRESSED AS PERCENTAGE OF DRY WEIGHT

TABLE 1. PERCENTAGE CALCIUM CONTENT, AVERAGE DRY WEIGHT OF 100 LEAVES, AND MILLIGRAMS OF CALCIUM IN 100 LEAVES, IN THE FOLIAGE OF THREE DECIDUOUS FOREST TREES DURING THE GROWING SEASON OF 1936

Species	Type of data	Dates when samples were collected									
		May 15	June 1	June 15	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1
American beech	Calcium content as percentage of dry weight	0.51	0.53	0.59	0.65	0.70	0.70	0.69	0.68	0.71	0.79
(*Fagus grandifolia* Ehrh.)	Weight in grams of 100 dry leaves	3.95	9.15	11.95	13.71	14.58	15.30	14.77	14.30	15.25	15.83
	Milligrams of calcium in 100 leaves	20.3	48.5	70.6	89.1	102.1	107.5	102.3	97.2	108.2	125.0
Cucumber tree	Calcium content as percentage of dry weight	0.30	0.55	0.90	1.05	1.23	1.35	1.35	1.33	1.33	1.51
(*Magnolia acuminata* L.)	Weight in grams of 100 dry leaves	6.05	22.10	34.20	44.65	52.50	56.73	55.60	55.55	60.52	60.60
	Milligrams of calcium in 100 leaves	18.1	120.1	315.8	468.5	642.0	766.0	751.0	738.3	804.2	915.0
Trembling aspen	Calcium content as percentage of dry weight	1.20	1.26	1.48	1.74	1.90	2.00	2.22	2.44	2.50	2.55
(*Populus tremuloides* Michx.)	Weight in grams of 100 dry leaves	16.30	24.26	29.08	31.05	31.71	32.30	32.33	32.07	33.06	33.80
	Milligrams of calcium in 100 leaves	195.6	318.0	431.0	542.0	602.3	646.0	719.9	782.0	826.1	865.0

the figure for May 15 being 0.51 per cent and that for October 1 being only 0.79 per cent. Cucumber tree had an even lower percentage-composition figure at the start, but had a calcium content of 1.51 per cent on October 1. Of the three species, cucumber tree budded the latest, and hence its foliage was at an earlier physiological stage of development on May 15. This would be sufficient to explain its relatively low calcium content on that date. The curve for trembling aspen showed that this species had a relatively high calcium content early in the season, and that the calcium content continued to increase until the time of leaf-fall. The weight of 100 dry aspen leaves on May 15 was 16.3 grams, indicating that this species had developed considerably by the first sampling date; hence one should take into consideration the fact that the first part of the seasonal curve is missing.

There seemed to be a tendency for the beech and cucumber-tree curves to flatten after July 15. The aspen curve did not exhibit this tendency until after August 15.

When the calcium content was expressed as milligrams per 100 leaves (figure 2), the same general tendencies existed except that the curve slopes steepened. Owing to the large size of the cucumber-tree leaves, the actual amount of calcium present in 100 of those leaves was very similar to that for aspen. Beech leaves are light in weight and low in calcium, and therefore they accumulate only small amounts of calcium when expressed on either a percentage or an actual-amount basis.

Because of the nature of the material, no attempt was made to express the results with the coniferous species on any basis other than that of percentage composition. These data are presented in table 2. The values

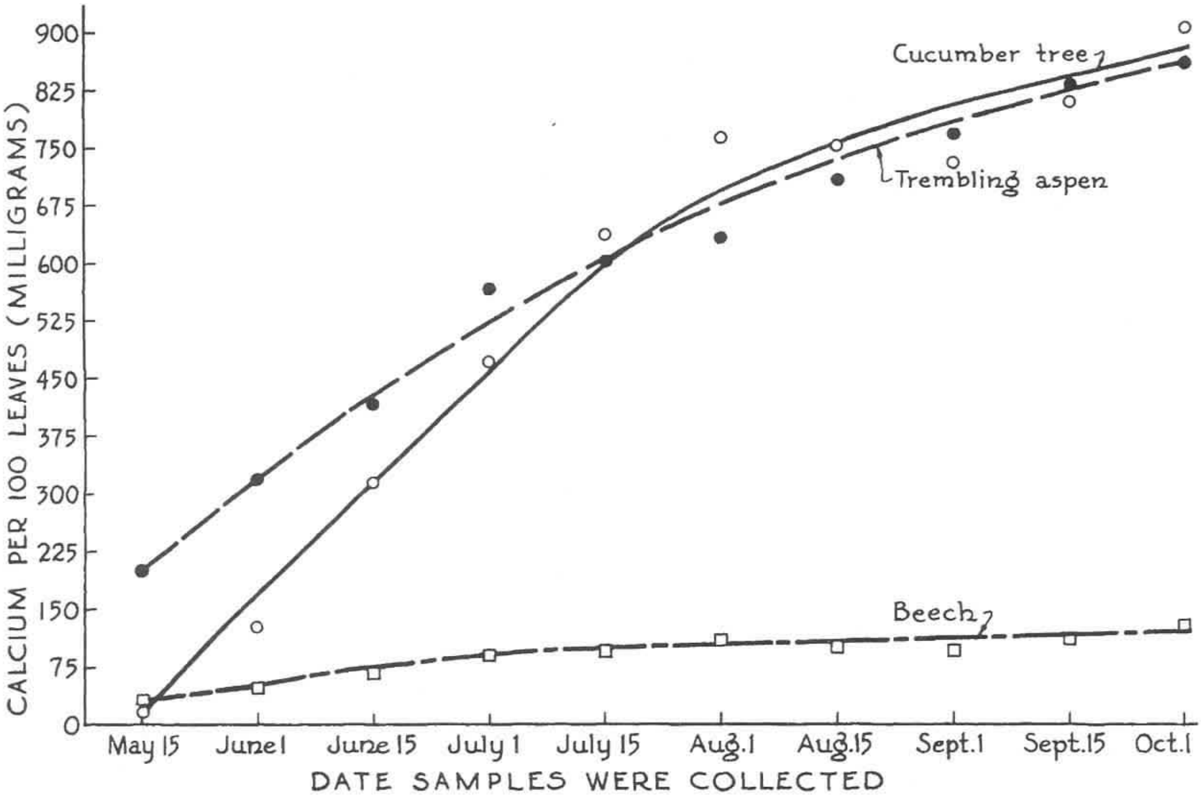

FIGURE 2. CALCIUM CONTENT OF THE LEAVES OF BEECH, CUCUMBER TREE, AND TREMBLING ASPEN THROUGHOUT THE GROWING SEASON, EXPRESSED AS MILLIGRAMS PER 100 LEAVES

TABLE 2. CALCIUM CONTENT OF FOLIAGE OF RED CEDAR AND WHITE PINE DURING THE GROWING SEASON OF 1936, EXPRESSED AS PERCENTAGE OF DRY WEIGHT

Species	Dates when samples were collected								
	June 1	June 15	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1
Red cedar, *Juniperus virginiana* L. (new foliage)	1.17	1.24	1.36	1.52	1.72	1.70	1.80	1.83	1.81
Red cedar (old foliage)	1.83	2.48	2.84	3.09	2.93	2.93	2.94	3.03	3.00
White pine, *Pinus strobus* L. (new needles)	0.20	0.27	0.31	0.36	0.40	0.44	0.47	0.48	0.52
White pine (one-year needles)	0.55	0.58	0.67	0.77	0.83	0.86	0.88	0.90	0.90
White pine (two-year needles)	0.81	0.84	0.89	0.93	0.97	1.04	1.07	1.11	....

for red cedar are shown graphically in figure 3, and those for white pine in figure 4.

It was somewhat difficult to separate the different-aged foliage of red cedar. However, it was possible to separate the foliage added during the 1936 season from that which was older, because the new foliage was light green as contrasted with the dark green color of the older tissues. It is interesting to note that the new foliage increased in calcium content from 1.17 per cent to 1.81 per cent; and that there was essentially no change during the winter, the old foliage having a calcium content which approximated that of the new foliage during the latter part of the growing season. The largest increase in calcium content seemed to occur in the old foliage between June 15 and August 1. After the latter date there seemed to be little change, the calcium content remaining at approximately 3.0 per cent during the remainder of the season.

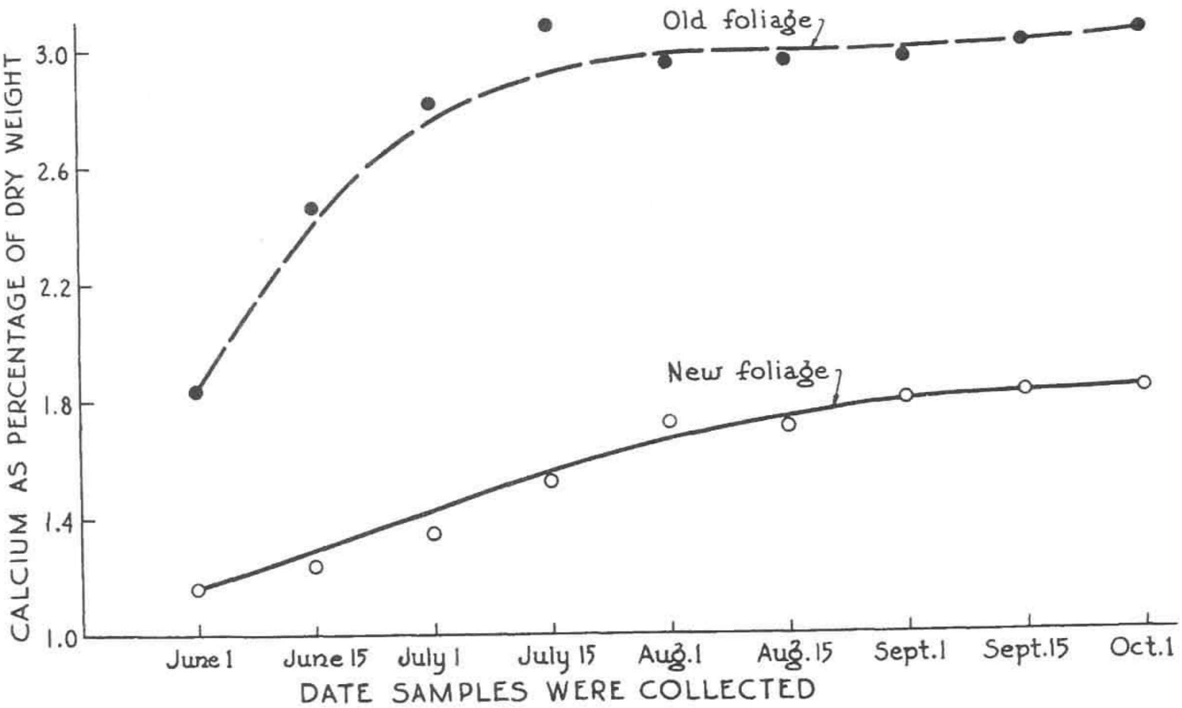

FIGURE 3. CALCIUM CONTENT OF NEW AND OF OLD RED-CEDAR FOLIAGE THROUGHOUT THE GROWING SEASON, EXPRESSED AS PERCENTAGE OF DRY WEIGHT

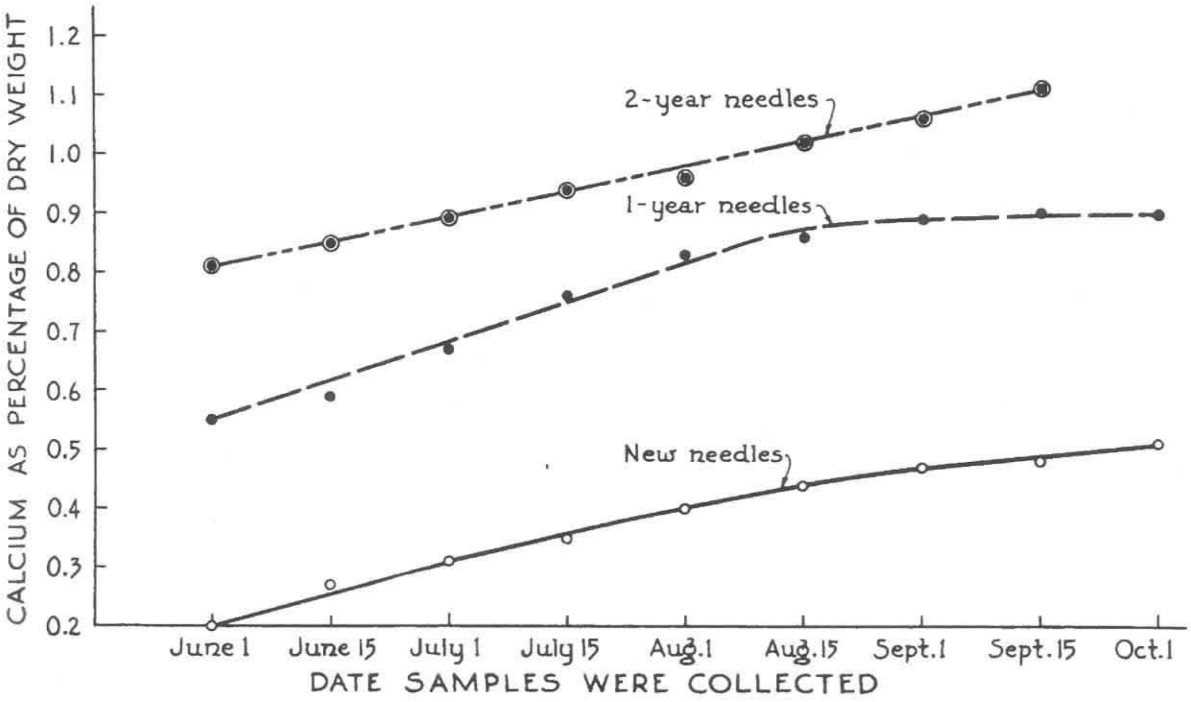

FIGURE 4. CALCIUM CONTENT OF NEW, ONE-YEAR, AND TWO-YEAR WHITE-PINE NEEDLES THROUGHOUT THE GROWING SEASON, EXPRESSED AS PERCENTAGE OF DRY WEIGHT

A similar relationship is seen in the case of white pine. The new needles accumulated calcium to the extent of 0.52 per cent of their dry weight, during the growing season. The one-year needles accumulated up to 0.90 per cent, and the oldest needles up to 1.11 per cent. The two-year needles started with less calcium than the one-year needles contained at the end of the season. This might indicate a loss of calcium during the winter. It would seem more likely, however, that the two-year needles had contained less calcium at the end of the previous growing season than the one-year needles contained at the end of the 1936 season. In order to study this phase more accurately, it would be necessary to sample the same group of needles for the entire three-years period that they remained on the trees.

The seasonal-trend data indicate that calcium accumulates steadily during the period of rapid growth, the rate of accumulation decreasing during the latter part of the summer. In the case of the evergreen trees, this accumulation ceases during the winter but is resumed in the following spring. The calcium content of the foliage of all the trees studied did not decrease just previous to the period of leaf-fall. Therefore an analysis of deciduous-tree leaves collected in the early fall, and of the oldest coniferous-tree needles, gives a good estimate of the amount of calcium returned to the soil. This method is decidedly advantageous as compared with taking samples of fallen litter, because by this method one can be certain that decomposition of the leaves has not started.

This fact was carefully checked in the fall of 1938. It so happened that no rain fell during the period of leaf abscission, and it was possible to obtain unweathered, freshly fallen litter. The fallen leaves of seven species were obtained and analyzed. The results were essentially the same as those obtained with leaves collected from the trees just previous to leaf-fall.

CALCIUM CONTENT OF MATURE FOREST-TREE FOLIAGE

The average calcium content of the mature foliage of the more common forest-tree species of the northeastern United States is reported in table 3. The figures given are the average results obtained from the numbers of trees specified. Since there is a considerable amount of variability among the individual trees of a given species, the average figures should not be considered exact. The trees are listed in order of decreasing calcium content. If the same species were sampled in another locality, it would not be unreasonable to expect that any one species might move as much as four places up or down from its position in table 3. As the table indicates, individual basswood-leaf samples were analyzed which contained as much as 3.9 per cent of calcium, and others which contained as little as 2.0 per cent. In spite of such variability, a review of the literature, as well as an examination of the writer's individual tree data, indicates that a given species tends to have a certain average calcium content, provided it is not growing on excessively acid soil (approximately below pH 4.5).

TABLE 3. PERCENTAGE CALCIUM CONTENT OF MATURE FOLIAGE OF 27 FOREST-TREE SPECIES

Species	Number of trees in sample	Calcium content, expressed as percentage of dry material	
		Range	Average
Tulip poplar (*Liriodendron tulipifera* L.)	14	2.98–3.69	3.24
Red cedar (*Juniperus virginiana* L.)	10	2.63–3.15	2.93
Basswood (*Tilia americana* L.)	26	2.00–3.90	2.81
Black locust (*Robinia pseudo-acacia* L.)	11	1.94–3.62	2.65
Mockernut hickory (*Carya alba* [L.] K. Koch)	10	1.68–3.84	2.62
Bitternut hickory (*Carya cordiformis* [Wang.] K. Koch)	10	1.90–3.36	2.50
White cedar (*Thuja occidentalis* L.)	13	2.06–3.10	2.48
Hop hornbeam (*Ostrya virginiana* [Mill.] K. Koch)	16	1.68–3.10	2.27
Trembling aspen (*Populus tremuloides* Michx.)	18	1.62–2.76	2.21
White ash (*Fraxinus americana* L.)	10	1.50–3.56	2.19
Black cherry (*Prunus serotina* Ehrh.)	4	1.88–2.40	2.14
Shagbark hickory (*Carya ovata* [Mill.] K. Koch)	10	1.34–2.46	1.94
American elm (*Ulmus americana* L.)	10	1.40–2.23	1.81
Sugar maple (*Acer saccharum* Marsh.)	85	1.06–2.91	1.75
Norway spruce (*Picea excelsa* Link)	6	1.52–1.71	1.60
White oak (*Quercus alba* L.)	15	1.22–1.46	1.36
Red oak (*Quercus borealis* Michx. f. var. *maxima* Ashe)	11	0.99–1.76	1.21
Yellow birch (*Betula lutea* Michx. f.)	34	0.96–1.52	1.21
Chestnut oak (*Quercus montana* Willd.)	6	0.80–1.55	1.20
White pine (*Pinus strobus* L.)	15	0.70–1.55	1.20
Balsam fir (*Abies balsamea* [L.] Mill.)	10	0.75–1.35	1.15
Red maple (*Acer rubrum* L.)	40	0.68–1.90	0.91
Red pine (*Pinus resinosa* Ait.)	13	0.50–1.05	0.80
Hemlock (*Tsuga canadensis* [L.] Carr.)	12	0.50–0.90	0.80
Beech (*Fagus grandifolia* Ehrh.)	65	0.50–1.50	0.75
Scotch pine (*Pinus sylvestris* L.)	10	0.50–0.80	0.69
Red spruce (*Picea rubra* [DuRoi] Dietr.)	10	0.44–0.73	0.62

The species can be arbitrarily divided into three groups on the basis of their calcium content. The first group would include those species with an average calcium content in excess of 2.0 per cent in their foliage, and would be the first eleven species listed in table 3 — tulip poplar, red cedar, basswood, black locust, mockernut hickory, bitternut hickory, white cedar, hop hornbeam, trembling aspen, white ash, and black cherry.

The species in this group might be called "soil improvers" because of the relatively large amounts of calcium which they deposit in the surface soil each year.

The second group would include species which contain from 1.0 to 2.0 per cent of calcium in their foliage — shagbark hickory, American elm, sugar maple, Norway spruce, white oak, red oak, yellow birch, chestnut oak, white pine, and balsam fir. These species might be considered as having a more or less neutral effect upon soil productivity, neither enriching it excessively nor depleting it seriously. Actual experience indicates that the first four members of this group (with the possible exception of Norway spruce) are mild soil improvers, and that the remaining species are mild "depleters".[1]

In the third group would be included those species containing less than 1.0 per cent of calcium in their foliage — red maple, red pine, hemlock, beech, Scotch pine, and red spruce. These may all be considered soil depleters.

DISCUSSION

The fact that the calcium content of forest-tree foliage continues to increase as long as the leaves remain on the tree is of considerable importance. It means that a maximum amount of calcium is returned to the soil at the time of leaf-fall. The probable reason for this is that the calcium is tied up in an insoluble form such as calcium oxalate, and hence is not free to move out of the foliage before the leaves fall.

The belief that the relative order in which the species are listed with respect to foliar calcium content (table 3) would not change greatly if trees of the same species were sampled in other regions, is supported by figures obtained from the literature. Alway, Maki, and Methley (1934) showed that basswood absorbed the largest amount of calcium of all the trees sampled in a study conducted in Minnesota. McHargue and Roy (1932) rated basswood as next to the highest in calcium content of 23 species sampled in Kentucky; they showed also that black locust and tulip poplar contained more than 3 per cent of calcium in their leaves. Coile (1937) showed that in North Carolina both tulip poplar and red cedar ranked very high in calcium content, while red maple and pine were very low in this respect.

One of the findings of the present study which should be emphasized is that not all coniferous trees are low in calcium and not all deciduous trees are high. Red cedar and white cedar, both members of the Pinaceae, are high absorbers of calcium. Red cedar particularly has a marked effect upon the pH and the structure of the soil. The writer has observed the soil beneath many clumps of red cedar and in no case has he failed to find it in good physical condition, the organic matter being incorporated to a depth of several inches. Earthworms usually were present.

Among the deciduous trees that are low in foliar calcium content are beech and red maple. The results obtained with these species are definite, because 40 analyses of red maple and 65 of beech constituted the data from which the average figures were calculated. Fortunately, neither of

[1]By "depleters" is meant species which tend to make moderately acid soil more acid, and which tend to form a mor type of humus layer, thus resulting in a low degree of incorporation of organic matter into the soil.

these species is valued very highly from the utilization standpoint, and therefore the trees can be removed from a stand without seriously affecting future returns from the forest.

The causal relationships involved between the calcium content of the litter and the incorporation of the organic matter into the soil are not too well understood. They may be due, in part, to the influence of a higher pH of the soil upon the numbers, kinds, and activity of the soil flora and fauna. Although several investigators have shown that earthworms are present in strongly acid soil, the fact still remains that the number and activity of the worms increases with an increased soil pH, provided other edaphic factors are favorable. There seems to be a relationship also between the palatability of forest-tree leaves and the calcium content. Work carried on by Johnston (1936) and further reviewed by Gast (1937) revealed that earthworms have some rather decided preferences among certain deciduous-tree leaves. Of the six species studied, under laboratory conditions, the worms preferred large-toothed aspen, white ash, and basswood to sugar maple and red maple, the leaves of the two maple species not being entirely consumed within a single season; red-oak leaves were not consumed at all. Similar results were obtained under field conditions except that the less palatable leaves were finally consumed after several years. Of course other fauna besides earthworms were involved under field conditions.

That these relationships are entirely concerned with the calcium content of the litter would hardly seem reasonable to suppose. It would seem more probable that the relationship between palatability and leaf type would involve the organic structure of the leaf — that is, the proportion of lignin, cutin, and the like, to the more readily digestible constituents. Nevertheless a general relationship between calcium content and palatability of the food for soil fauna seems to exist and therefore can be used as a guide, regardless of the causal relationship involved.

The writer does not mean to imply that any forest soil can be maintained in a high state of productivity merely by growing high-calcium species on the area. It must be considered that climate, geological origin, topography, and vegetation all play an important part in the development and maintenance of productive soils. Even by maintaining hemlock or pine on a highly calcareous soil, it would take many tree generations to deplete the surface soil of its reserve of calcium and to produce an acid, unproductive soil. Some of the most acid soils will not support a stand of the high-calcium-absorbing species, and if such soils did support such a stand the calcium content of its foliage would probably decrease considerably. When sugar maple is growing under average soil conditions, as on a Lordstown silt loam soil at pH 5.4, the species usually contains about 1.7 per cent of calcium in its foliage. If the species were growing on an extremely acid soil, as Beckett sandy loam with a pH of 3.65 in the surface soil, the average tree would contain only about 0.9 per cent of calcium in its leaves. On the other hand, if the species were growing on a highly calcareous soil such as Farmington or Honeoye silt loam, the calcium content usually would not be any higher than on the Lordstown silt loam of medium acidity. From data obtained, it appears that if the soil is 50 per cent or more saturated with bases in the surface soil, the

amount of calcium absorbed will not be affected. But where soils are 20 to 30 per cent base-saturated, a reduction in calcium absorption seems to occur. The species that normally absorb relatively large amounts of calcium, however, are not generally found occurring abundantly on very acid soils. In the Adirondack region, as the soils get extremely acid, sugar maple tends to drop out of the stand. As the proportion of sugar maple decreases, the proportion of red maple increases. One of the weaknesses of this study was due to the fact that not all the species could be sampled growing on the same soil type in the same region. If balsam fir and red spruce occurred naturally on Lordstown soil near Ithaca, it might be that they would exhibit a higher calcium content of foliage.

It is hoped that the silviculturist and forest manager will consider each tree species in the light of its influence upon the productivity of the soil, and, when making selection and stand-improvement cuttings, will tend to favor those species which, according to available findings, help to maintain or to increase the fertility of the soil. It is suggested, of course, that he consider this as only one phase in his forest-management program. To the extent that a species is highly valuable from the economic standpoint, he could not afford to remove it permanently from a stand. Hop hornbeam is a good example of such a species; it is considered a weed by most foresters, and yet its calcium content is relatively high.

SUMMARY

The seasonal trends in calcium content of the foliage of five forest-tree species were studied. In all cases the calcium content, expressed either on a percentage or on an absolute-amount basis, was found to increase progressively throughout the growing season.

The calcium content of the foliage of evergreen trees increased throughout the growing season but remained fairly constant during the winter months. The longer the foliage of a single species remained on the tree, the higher was its calcium content.

The calcium content of mature foliage of twenty-seven forest trees was determined. The trees were conveniently placed in three groups with respect to their calcium content. In the first group were the species averaging more than 2.0 per cent of calcium in their foliage—tulip poplar, red cedar, basswood, black locust, mockernut hickory, bitternut hickory, white cedar, hop hornbeam, trembling aspen, white ash, and black cherry. In the second group were the species whose foliage contained from 1.0 to 2.0 per cent of calcium—shagbark hickory, American elm, sugar maple, Norway spruce, white oak, red oak, yellow birch, chestnut oak, white pine, and balsam fir. In the third group were the species whose foliage contained less than 1.0 per cent of calcium—red maple, red pine, hemlock, beech, Scotch pine, and red spruce.

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